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WHITE PINE BLISTER RUST OUTBREAK ON THE LINCOLN NATIONAL FOREST AND MESCALERO-APACHE INDIAN RESERVATION, NEW MEXICO

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517 Gold Avenue, SW
Albuquerque, New Mexico 87102

INTRODUCTION

White pine blister rust (WPBR), Cronartium ribicola, was found in 1990 on southwestern white pine (SWWP), Pinus strobiformis, on the Lincoln National Forest (LNF) near Cloudcroft, New Mexico (Hawksworth 1990). Subsequent surveys have shown that this non-native fungal disease is present virtually throughout the range of SWWP in the Sacramento Mountains and adjoining White Mountains in south-central New Mexico. Roughly one-half million acres, including portions of Cloudcroft, Mayhill, and Smokey Bear Ranger Districts of the LNF, the Mescalero Apache Indian Reservation (MAIR), and small parcels of private land, are affected (see appendix).

This outbreak was unexpected because the closest known populations of the fungus were several hundred kilometers away, in Wyoming and California. The source of the outbreak is unknown, and may be a result of planting either infected SWWP or Ribes, the alternate host for the disease, within this area. It is also possible (though perhaps unlikely) that spores of the fungus arrived and germinated after long-distance aerial flight.

It appears that this outbreak will, over time, cause severe damage to the large SWWP population in this area. Based on comparative greenhouse studies, SWWP is highly succeptible to the rust (Hoff, et al 1980), and moreover, the climate may be well-suited to the fungus. Peterson and Jewel (1968), suggested, perhaps prophetically, that the rust might "explode" if it ever reached the relatively moist, high elevation sites with SWWP in the Southwest.

This report describes the nature of the disease, summarizes our initial efforts to monitor this outbreak, describes the development and current status of this outbreak, and discusses its potential impacts. Also discussed are possible approaches for research and management.

NATURE OF THE DISEASE

WPBR is thought to be native to Asia, where it has caused relatively little damage. It gradually spread into Europe during the 1800's on plantings of eastern white pine, Pinus strobus. It was brought to both eastern and western North America on white pine planting stock from Europe around the turn of the century. Since then the disease has caused extensive damage to several species of white pine, particularly in the Northern Rockies, Pacific Northwest, and California (Mielke, 1943; Benedict, 1981).

Like other rust diseases, WPBR has a complex biology. The life cycle of the fungus involves several different types of spores and an alternate host, Ribes spp. (a currant or gooseberry). The progression of the disease on a pine can be relatively simple, however. After infecting through a needle, the fungus grows through the inner bark of a branch, and, depending on the location of the infection, may reach the main stem. When the fungus grows completely around the stem, the top of the tree dies. The fungus can then continue growing down the stem, eventually killing the entire tree.

Blister rust will kill white pines of all sizes. However, small trees are killed much more quickly than large ones. In this outbreak, we have observed that infections often occur through needles on the terminal of young trees, resulting in top-kill within a few years. Mature trees typically survive for many decades after infection, because it usually takes a long time for the fungus to reach and girdle the trunk.

The fungus can grow up to two or three inches each year along a branch, although often the rate is much slower. Natural self-pruning of branches eliminates many rust infections before they can grow into the trunk.

Sometimes trees are severely damaged or killed by multiple branch infections, before the fungus has had time to encircle the main stem. A sizable tree may have a hundred or more separate rust infections within its crown.

The most readily visible symptom of the disease is branch "flagging," which occurs after the fungus has girdled a branch and killed the distal portion. Flagging occurs several years after initial infection, so it may not be present in areas recently invaded by the rust. After causing flagging, the fungus often continues growing inward until it reaches the main stem or until the branch dies from other causes.

Prior to flagging, infections produce tapered swellings (cankers) which elongate along the branches. These can be similiar in appearance to the swellings produced by dwarf mistletoe. Three or four years after infection, the characteristic white/orange blisters (aecia) may erupt through the bark of a canker.

In this outbreak, we have found that aecia begin appearing in early to late April, depending on spring temperatures and the particular site. After breaking open to disperse their spores, the blisters disintegrate, and are generally gone by sometime in June. After this, the cankers have a somewhat rough, blackened appearance. Active cankers may produce aecia each spring for several years.

The spores produced in the aecia are the ones that infect Ribes. These spores can travel long distances, perhaps hundreds of miles (Mielke, 1943), to spread the disease. Rust colored areas (uridia) appear on the underside of infected Ribes leaves in the summer.[1] From these, spores are produced which can infect additional leaves and other Ribes bushes, resulting in a buildup of inoculum. Somewhat later, hairlike structures (telia) develop on Ribes leaves. These produce the spores that infect white pines. These spores usually do not remain viable long enough to infect pines more than a few hundred yards away (Benedict, 1981).

The disease causes relatively little damage to Ribes bushes, and the infection dies when the leaves are shed in the fall. Thus WPBR is an annual disease on Ribes and a perennial disease on pine.

[1]The WPBR fungus on Ribes is very difficult to distinguish from the native pinon blister rust, Cronartium occidentale, which occurs on Ribes throughout much of the Southwest.

Blister rust spores require cool temperatures and high moisture conditions to germinate and cause infection (Mielke, 1943). The summer rainy season of the Southwest may provide conditions very favorable for disease spread and intensification. Although a dry spring may prevent infections on Ribes some years, effectively breaking the cycle, other years will experience enough moisture to get infection from pine to Ribes. Then, when the usual summer rains begin, buildup can occur on Ribes. Moisture is usually available in late summer and early fall, the time when new infections occur on pine.

TRACKING THE OUTBREAK

After the rust was found in March 1990, District, Forest Pest Management (FPM), and Rocky Mountain Experiment Station (RMS) personnel began informal surveys to determine the extent of the outbreak. It soon became apparent that the disease had already spread throughout most of the range of SWWP in the Sacramento Mountains, including the Mescalero-Apache Indian Reservation, although in most areas there was little or no visible damage.

In 1991 we found infected pines at several locations in the adjoining White Mountains, north of Ruidoso, NM.

Examinations of white pines in several other ranges in southern and central New Mexico were made in 1991 and 1992. No blister rust was detected in these populations, nor has it been found anywhere else in the Southwest.

During the summer of 1990 we began establishing a small set of "rust behavior" plots to help monitor the development of the disease and damage over time. Initial readings were made on the plots in the spring of 1991. Information was collected on tree size, number of rust infections, and visible damage. Also noted were the approximate age of rust cankers, their location within the crown, and whether or not they were fruiting (producing aecia). Trees were tagged for periodic remeasurement. Pruning was done on one of the plots to test its feasibility for controlling the disease.

These plots were re-examined in the Spring of 1993, with our observations summarized below.

Silver Springs Canyon Plot

This plot is located three miles northeast of Cloudcroft, about a mile from where WPBR was first discovered along highway 24. It lies in a mixed-conifer stand which has a high proportion of SWWP. The sample consists of 41 SWWP, including saplings, poles, and mature trees.

WPBR cankers were found on all but two trees (small suppressed saplings). In 1991 roughly 430 cankers were noted, and in 1993 over 500. The majority of the cankers originated about 1985; more recent infections took place between 1988 and 1990. A few older cankers dating from about 1980 were observed.

Between 20 and 30 percent of the cankers were sporulating. Most of the sample trees had at least one sporulating canker. At least 26 of the trees, many of them pole-size, had stem cankers or other "lethal" cankers (i.e. those within a

few inches of the stem). It appears that most of these these will be top-killed by the fungus within the next 10-20 years, depending on their size.

In 1991, only 9 of the trees had any flagging. Ten additional trees were flagging in 1993. Although rust incidence is relatively high here, it is even higher further down this canyon and in nearby Bradford Canyon, where many trees have already been severely damaged or killed.

Wills Canyon Plot

This plot is located about 12 miles south of Cloudcroft in an area that was logged about 1985. The remaining stand is fairly open, and is over half SWWP, with the remainder mostly Douglas-fir (DF). The sample consists of 45 SWWP, and includes saplings, poles, and mature trees.

In 1991, 12 of the sample trees appeared to have WPBR cankers. Sporulating cankers were seen on only 3 of the trees. No rust-caused flagging was noticed.

In 1993, 18 trees appeared to have visible cankers, and sporulating cankers were seen on 4 trees. Flagging had occurred on a few trees, but was not very noticeable on the plot.

A total of 27 cankers were noted in 1991, and 58 in 1993. The oldest cankers on this plot appear to have originated about 1985. The majority of the cankers originated between 1988 and 1990. Approximately 90% of the cankers were latent (non-sporulating), both in 1991 and 1993.

The only lethal canker we found was on a small sapling.

Poison Spring Canyon Plot

This plot is on the southern portion of the MAIR, about 8 miles northeast of Cloudcroft. The stand was thinned in 1990, and consists primarily of SWWP, with lesser amounts of DF and ponderosa pine (PP). The sample consists of 52 SWWP, mostly poles and large saplings.

In 1991, 20 of the sample trees appeared to have WPBR infection; however, no sporulating cankers were seen. In 1993, an additional 3 trees appeared to be cankered. Two of the 52 trees had sporulating cankers.

About 80 cankers (swellings) were noted in 1991, and around 100 in 1993. Most of the swellings appear to have originated around 1985, and during 1988-90. There are a few swellings that appear to have originated about 1980; these seemed to be inactive.

There is some flagging on this plot, but most, if not all of it seems to be caused by Atropellis canker, a native fungal disease that is quite abundant in this stand. Although rust cankers are fairly common here, little damage from WPBR is expected for many years.

Hay Canyon Plot

This plot is located in a SWWP plantation in Hay Canyon (approximately 10 miles south of Cloudcroft), established about 1979. The plot is about two acres in

size and includes 357 SWWP. In 1991, over 90% of the trees were visibly infected with WPBR. (Nearly all the remaining trees were stunted and/or suppressed.)

At the time of plot establishment, most of the trees had multiple sporulating rust cankers, but only minor amounts of "flagging" were visible. Most of the sporulating cankers appear to have originated about 1985. Swellings (new cankers) originating in 1988 and/or 1989 were also fairly common. There were, however, occasional dead SWWP that probably were killed by the disease a year or two earlier. These appear to have had older (pre-1985) infections that were present at relatively low levels in the plantation.

In the spring of 1993 there was somewhat more flagging, but the great majority of the rust cankers had not yet caused branch or top-kill. To a casual observer, the plantation would have still looked relatively healthy.

In 1991, to test the efficacy of pruning for controlling the disease, we pruned all the trees (137) on the plot that did not already appear to have lethal cankers. Pruning has been used in efforts to control WPBR in other parts of North America (Hunt, 1991; Hagle and others, 1989).

Pruning has been done, not only to remove branches with rust cankers, but also as a preventative measure. By removing the entire lower crown in young trees, the probablity of infection is decreased. (Data from previous outbreak areas has indicated that rust infection is most common in the lower crown.)

We removed all lower branches, leaving 2-3 whorls at the top of the trees. Hundreds of rust cankers were removed, many of them potentially lethal. The other 220 trees on the plot already had rust that could not be effectively removed, and were not pruned. These were/are expected to die within in a few years.

In 1993, it was apparent that many of the pruned trees had lethal cankers in the upper crown (originating in 1989 or 1990), typically on the stem. Although we think that the pruning "saved" many of the trees, it seems probable that future "waves" of infection will result in more lethal cankers, eventually killing even more of the pruned trees.

DEVELOPMENT OF OUTBREAK AND CURRENT STATUS

It appears that the rust has been on the Cloudcroft Ranger District (RD) since the early to mid-1970's, based on the apparent age of the oldest rust cankers that have been found. For several years, the disease was probably at very low levels where it occurred, and was not nearly as widespread.

A few rust cankers found in Bradford Canyon (where the outbreak was first detected) appear to be among the oldest infections. This site, along Highway 24, has some of the most severe WPBR damage, and is possibly where the disease originated. Even so, nearly all the damage in this area is from infections which occurred about 1985. Older infections are relatively scarce. Moreover, we have found a few other sites, several miles from Bradford Canyon, that also have infections which appear to have originated in the early to mid-1970's. Thus, it is unclear where the outbreak started.

As determined from our plots and from observations made in many other locations, there was a big "wave" of infection about 1985. Probably weather conditions that year were particularly favorable for spread and intensification of WPBR.[1] It spread throughout the Sacramento and White Mountains, with the number of infections on pine increasing many fold.

Significant amounts of new infection occurred on SWWP at least twice between 1988 and 1990. Spores from the 1985 infections were being dispersed those years, resulting in these new "waves" of rust infection. In 1992 and 1993, many of these younger cankers began releasing spores. We are thus seeing a continual buildup of inoculum, and can expect that the disease will continue to intensify.

Nineteen-ninety was very likely the first year that much visible damage--flagging from the 1985 infections--began showing up. By 1993, rust damage had become noticeable in many more locations on the Cloudcroft and Mayhill RDs. Additional flagging from the 1985 infections had occurred, and flagging from more recent infections was starting to appear.

Considerable mortality of young trees has already occurred at several locations, particularly along Highway 24, and in several of the canyons south of Cloudcroft.

Damage is particularly severe in the 2200+ acres of young SWWP plantations on Cloudcroft RD, where infection rates typically exceed 90 percent. Several plantations have already experienced considerable top-kill and mortality. Nearly complete losses can be expected.

SWWP was planted on the Cloudcroft RD from 1977[2] to 1990, with seedlings grown at an Idaho nursury. The high infection rates in these plantations suggests that the disease may have been introduced on the planting stock. However, as discussed previously, it appears that the rust was already present in the Forest prior to 1977. Therefore, it is possible that the rust spread into the plantations after they were established. The plantations have a lot of Ribes in them, which would have allowed for rapid intensification of the disease.

Infection rates in natural stands are generally lower than in the plantations. Even so, the rust is already widespread in the mixed-conifer forests of the Cloudcroft and Mayhill RD's. There is a wide range in the incidence of the disease from location to location, but it can be found virtually everywhere that has significant amounts of SWWP, including many stands that are ponderosa pine type. The disease is usually more abundant on the moister sites.

[1] Interestingly, there was also a major spread and intensification of WPBR in California in the mid 1980's (B. Kinloch, personal communication).

[2] There are apparently no records indicating that white pines were planted on the LNF prior to 1977.

We estimate that there are already a few thousand acres experiencing levels of infection similiar to that in the Silver Springs Canyon plot, where most trees have multiple infections and flagging is quite noticeable. In these areas, extensive top-kill and mortality can be expected within the next few decades.

The Wills Canyon plot, where less than half the trees appear to be infected and only a little visible damage has occurred, seems typical of many thousands of acres of drier mixed-conifer forest. It appears that the disease will develop more gradually on many of these sites.

Infection is still relatively low on most portions of the MAIR and further north on the Smokey Bear RD. So far, only occasional flagging has been observed. Infections are widespread, however, and damage will become more noticeable in the next few years.

The fact that the disease has not been found anywhere else in the Southwest suggests that it was introduced by the planting of infected pines or Ribes. If the rust arrived by long-distance aerial dispersal, we would expect that it would have also reached other SWWP populations in the Southwest.

It is possible, however, that the disease _has_ reached other parts of the Southwest, but has not yet been detected. New outbreaks of WPBR have often gone undetected for many years (Mielke, 1943). Complicating the puzzle is the possibility that the disease could have already spread from the Sacramento/White Mt. outbreak to other mountain ranges in the Southwest.

POTENTIAL IMPACT

It is likely that WPBR will cause severe and extensive damage to the SWWP population in Sacramento and White Mountains. This population of _Pinus strobiformis_ is probably the largest anywhere. We expect that the disease will eventually reduce the population to a small fraction of its present size, and could even wipe it out entirely (R. Peterson, personal communication).

Along with the high succeptibility of SWWP and a climate favorable to the rust, the large population will itself increase the intensity of the outbreak, due to the potential for large amounts of inoculum to build up.

Finally, _Ribes,_ the alternate host, is common in the Sacramento Mountains. The most common species, _Ribes pinetorum,_ the orange gooseberry, is quite succeptible to the rust (Hawksworth and Conklin, 1990). This plant is often found along drainage bottoms and in open, cut-over areas, where it often becomes a large shrub.[1] It appears to provide an ample source of inoculum for infection of white pine.[1]

SWWP is a major component of the mixed-conifer forests throughout much of this area, and even occurs in nearly pure stands in limited areas, typically near drainage bottoms. About 3,400 acres on the Cloudcroft and Mayhill RDs have been

[1]_Ribes_ seems to be less common on the MAIR than it is on the Cloudcroft and Mayhill RDs. Because of this, the outbreak may be somewhat less severe on the Reservation than on much of the LNF.

identified as white pine cover type, which indicates a unique situation botanically for the Southwest.

Overall, we estimate that SWWP comprises about fifteen percent of the total stems in the 232,000 acres of mixed-conifer forest on the LNF, and a somewhat smaller proportion in the 82,000 acres of mixed-conifer on the MAIR. SWWP also occurs in significant amounts in many ponderosa pine stands in these mountains.

SWWP is a commercial timber species and has typically carried the same stumpage value as ponderosa pine. It has been favored as a "crop" tree in many managed stands because of the high incidence of dwarf mistletoe on ponderosa pine and Douglas-fir. SWWP regenerates well and had been successfully planted on the Cloudcroft RD for several years.

The tree is equally important for watershed protection, scenic qualities, and its value to wildlife. The effects on species composition and biodiversity may be the most significant potential impact of the WPBR outbreak.

Uncertainties necessarily exist in regard to the rate at which the outbreak will develop and losses will occur. However, with the large wave of infection that occurred in the mid 1980's, followed by at least two more recent waves, the rust, if not "exploding," at least seems to be developing at a very healthy (sic) rate. Further monitoring will determine the magnitude of the most recent waves of infection, and make more accurate predictions possible.

We can expect a slow, insidious effect from the disease over the next several decades. Thirty to fifty years from now there will still be a lot of large white pines surviving, but there will be major deficiencies in the smaller size classes over much of the affected area. A large proportion of the seedlings and saplings now present will have died. Regeneration will still occur, but most of it will succumb relatively quickly.

MANAGEMENT AND RESEARCH

Since its introduction into North America, many strategies have been used in attempts to control WPBR. For several decades, large-scale Ribes-eradication programs removed the alternate host within and adjacent to concentrations of white pines. These efforts were largely discontinued in the 1960's, due to rising costs and relative ineffectiveness (Benedict, 1981).[1]

During the 1950's and 60's, antibiotic fungicides were tried, but this approach eventually proved to be of little benefit. More recently, the main focus of WPBR control efforts has been the use of genetic resistance.

We will continue to monitor the LNF/MAIR outbreak, and survey for the rust in other mountain ranges in the Southwest. We are planning to establish additional permanent plots to gather more data on the outbreak in the Sacramento/White Mts. We will also begin searching for SWWP that might be genetically resistant to WPBR.

[1] More recently, "Ribes reduction" has been recommended as part of an integrated management approach to reduce rust hazard in the northern Rockies (Hagle and others, 1989).

We have been concerned about reducing the possibility of people spreading the disease to other parts of the Southwest. The New Mexico Department of Agriculture has adapted an internal policy prohibiting commercial digging of white pine and Ribes from the LNF and private lands in its vicinity. The LNF and the Mescalero Agency have both agreed to prohibit the removal of living white pines and Ribes, both commercial and noncommercial, from their lands. The New Mexico Division of Forestry has taken measures to insure that commercial diggers who operate in the Sacramento Mt. area can distinguish between SWWP and other species.

In 1990, based on our recommendations, the LNF discontinued planting SWWP. Efforts to plant more SWWP there would almost certainly be futile, at least until a time when resistant stock might be available for testing.

In thinning stands, particularly those where dwarf mistletoes are a problem on ponderosa pine or Douglas-fir, we recommend leaving more SWWP (closer spacing) to allow for eventual losses to the rust. Leaving more white pines will also increase the chance of having some resistance in a stand. Denser stands will limit the growth and development of Ribes. Marking crews will need to become familiar with the disease to help insure good crop tree selection. Trees with cankers on or near the main stem, and those with numerous branch cankers, should be selected against.

It appears that pruning will not be effective for controlling the disease in plantations on the LNF because of the severity of the rust. Large numbers of infections are occuring in the upper crowns. Pruning may have some application on sites where the disease is less severe, particularly in recreation sites and other high-use areas.

The Rocky Mountain Forest and Range Experiment Station (RMS) has recently outlined proposed research on the outbreak (Geils, 1993). One of their interests is the development of a site-specific "rust hazard model," similar to one developed for WPBR in Idaho (McDonald and others, 1981). The model would incorporate weather, tree growth, and rust information, and would be used to make predictions about the outbreak.

Another focus of RMS would be an "ecological effects assesment" which would generate information on direct and indirect effects of the outbreak. A related study got underway on the LNF in 1993 (Lundquist, 1993), in which scientists are examining "disturbance pathways" in the forest, with particular focus on impacts to the Mexican Spotted Owl.

RMS has also suggested studies on the genetic variability of Cronartium ribicola and Pinus strobiformis. This would be relevent for development of the hazard model and the ecological assessment, and also for any future efforts to work with genetic resistance to WPBR in SWWP.

Genetic resistance to WPBR has been demonstrated in natural populations of other white pine species (Bingham, 1983; Kinloch, 1970). Beginning in 1950, tree improvement progams have worked with resistance under controlled conditions to develop resistant planting stock for western white pine, and more recently, for sugar pine. So far results have been encouraging, although the ultimate success of these efforts is uncertain.

The value and feasibility of a breeding program for SWWP has been and will continue to be a topic of discussion. Regardless of whether such a program eventually develops, we believe there is value in determining what resistance may exist in SWWP, and in locating potentially resistant trees. It may be possible to utilize natural resistance and appropriate cultural practices (Hoff and others, 1976) to help insure the survival of the Sacramento Mt. SWWP population.

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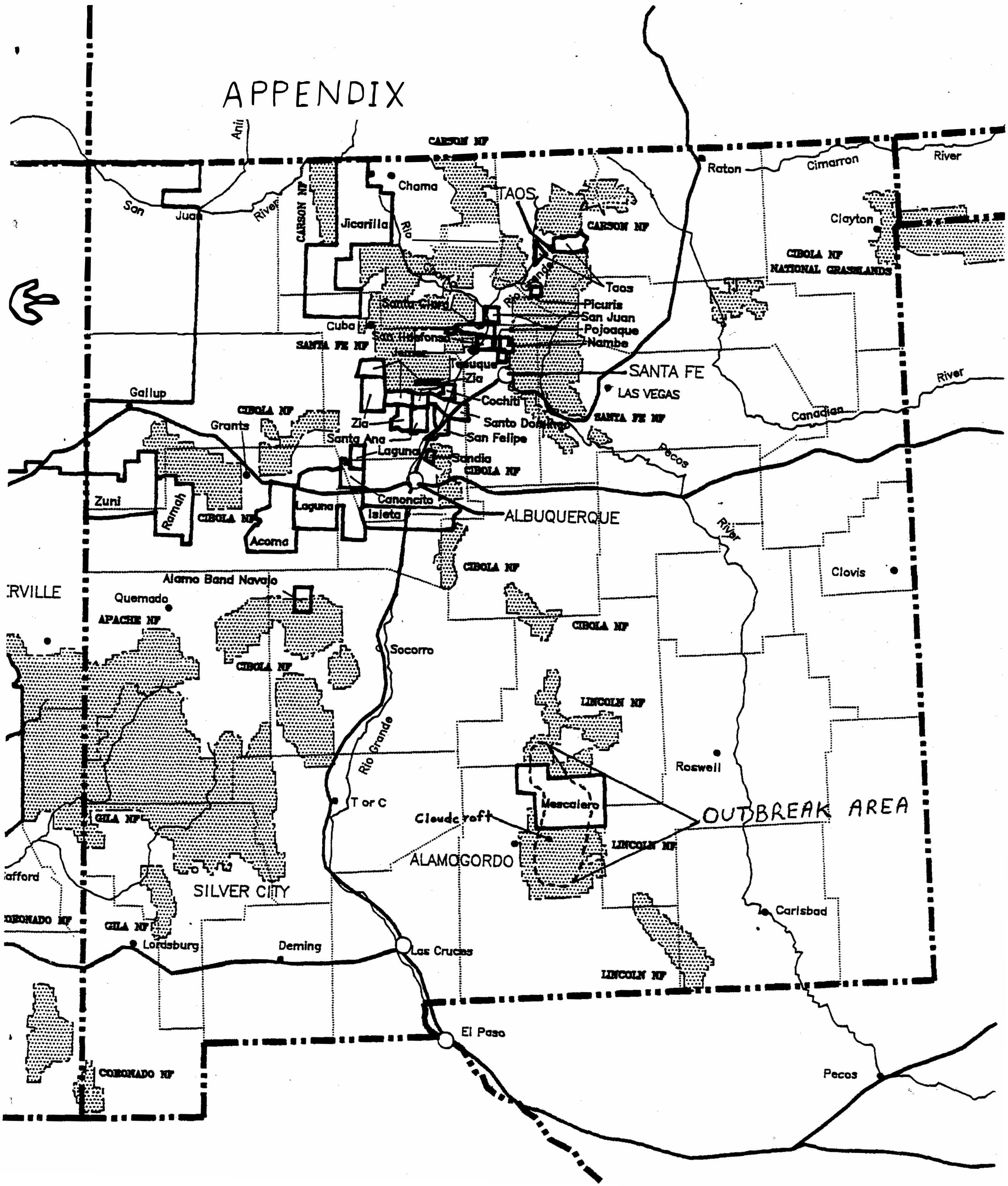
APPENDIX



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